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Pulsed Dose Delivery of Oxygen in Mechanically Ventilated Pigs with Acute Lung Injury

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14. ABSTRACT

Acute lung injury (ALI) is a common condition that leads to respiratory impairment with patients, specifically regarding oxygenation. We have previously demonstrated in a mechanical model that using a portable oxygen concentrator (POC) with pulsed dose delivery of oxygen is an alternative to continuous flow to conserve oxygen and prolong battery life, while still maintaining adequate oxygen delivery. We hypothesize that using a modified POC and pulsed dose oxygen delivery can provide similar oxygenation in an animal model compared to continuous flow oxygen delivered to a reservoir bag. In a crossover study, we induced ALI in 15 locally bred pigs using an oleic acid model. We ventilated the pigs with equipment that is used by Critical Care Air Transport Teams of the United States Air Force. Each animal served as its own control as we compared oxygen delivery using a POC in both continuous flow with a reservoir bag and pulsed dose. We performed this in both volume control and pressure control mechanical ventilation. There was no statistical difference regarding any of the ventilator variables including respiratory rate and tidal volume in the ventilator modes or in oxygen delivery methods, with the exception of mean airway pressures (4.1±0.9 cm H_2O vs. 6.5±2.7 cm H_2O, p=0.03). There was no between groups for the pulsed dose delivery and continuous flow. In volume control, pulsed dose oxygen delivery demonstrated a significant increase in the P:F ratio (168.8±96.1 vs. 91.7±65.4, p=0.002) compared with continuous flow. However, this was not seen in pressure control ventilation (89.0±74.5 vs. 79.1±65.4, p=0.67). We were able to demonstrate that oxygen delivery using a POC in mechanically ventilated pigs with ALI is feasible. We were also able to demonstrate that pulsed dose delivery from a POC is superior to continuous flow oxygen delivery for oxygenation in acute lung injuries when using volume control. We propose that this is a safe alternative to conserve oxygen in the transport of critically ill patients, although human studies are required.

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1.0 SUMMARY

Acute lung injury (ALI) is a common condition that leads to respiratory impairment with patients, specifically regarding oxygenation. We have previously demonstrated in a mechanical model that using a portable oxygen concentrator (POC) with pulsed dose delivery of oxygen is an alternative to continuous flow to conserve oxygen and prolong battery life, while still maintaining adequate oxygen delivery. We hypothesize that using a modified POC and pulsed dose oxygen delivery can provide similar oxygenation in an animal model compared to continuous flow oxygen delivered to a reservoir bag. In a crossover study, we induced ALI in 15 locally bred pigs using an oleic acid model. We ventilated the pigs with equipment that is used by Critical Care Air Transport Teams of the United States Air Force. Each animal served as its own control as we compared oxygen delivery using a POC in both continuous flow with a reservoir bag and pulsed dose. We performed this in both volume control and pressure control mechanical ventilation. There was no statistical difference regarding any of the ventilator variables including respiratory rate and tidal volume in the ventilator modes or in oxygen delivery methods, with the exception of mean airway pressures (4.1±0.9 cm H_2O vs. 6.5±2.7 cm H_2O, p=0.03). There was no between groups for the pulsed dose delivery and continuous flow. In volume control, pulsed dose oxygen delivery demonstrated a significant increase in the P:F ratio (168.8±96.1 vs. 91.7±65.4, p=0.002) compared with continuous flow. However, this was not seen in pressure control ventilation (89.0±74.5 vs. 79.1±65.4, p=0.67). We were able to demonstrate that oxygen delivery using a POC in mechanically ventilated pigs with ALI is feasible. We were also able to demonstrate that pulsed dose delivery from a POC is superior to continuous flow oxygen delivery for oxygenation in acute lung injuries when using volume control. We propose that this is a safe alternative to conserve oxygen in the transport of critically ill patients, although human studies are required.

2.0 INTRODUCTION

Acute lung injury (ALI) is a common condition leading to respiratory impairment in patients and is characterized by impaired oxygen delivery, loss of the protective barrier function of the lung tissue, and buildup of fluid and protein within the lungs. ALI is diagnosed, in part, by comparing the ratio of arterial oxygen concentration (P_aO_2) to the percentage of oxygen in the air used for breathing (fraction of inspired oxygen, F_iO_2). ALI is defined as a P_aO_2: F_iO_2 (P:F) ratio of <300, while a ratio of <200 is characteristic of acute respiratory distress syndrome [1]. While the exact mechanism of ALI has not been clearly defined, several conditions are known triggers, including trauma, blood transfusions, severe infections, pneumonia, inhalation injuries, and severe systemic inflammation [2]. Because of their respiratory impairment, patients often require intubation and mechanical ventilation with supplemental oxygen and positive end-expiratory pressure (PEEP). To date, the only intervention demonstrated to improve outcomes in acute respiratory distress syndrome has been the use of lung protective ventilation with tidal volumes of 6 mL/kg of predicted body weight [3].

When patients with ALI are transported while mechanically ventilated, the use of portable oxygen is necessary. Historically, this has been accomplished using compressed oxygen cylinders or liquid systems. Conventional oxygen systems consist of compressed oxygen at 2200 psig and are large, heavy, and carry a finite supply of oxygen with an explosive risk. Liquid systems are heavy, are constantly off-gassing, and can cause burns if spilled. Military and

austere environments present a number of additional challenges for oxygen delivery. The logistics of shipping either type of oxygen system is expensive secondary to the weight and dangers of transport.

The United States Air Force (USAF) has the responsibility of transporting injured service men and women from forward-deployed locations. In the 1990s, the concept of Critical Care Air Transport Teams (CCATTs) was developed to provide for critically injured and mechanically ventilated patients. These teams use specialized equipment that must be both mobile and able to perform in austere environments [4]. Oxygen, in these situations, is particularly difficult, for reasons mentioned above. Currently, USAF aeromedical transport doctrine prohibits compressed gas cylinders aboard aircraft.

Portable oxygen concentrators (POCs) were originally developed for patients requiring home oxygen therapy who desired alternatives to compressed oxygen [5,6]. They have been shown to be efficacious in hospitalized patients requiring oxygen therapy [5]. Because there is a limit to the rate at which oxygen can be produced from POCs (approximately 3 Lpm with continuous flow), more efficient means of delivering oxygen were devised to deliver high concentrations of oxygen continuously. As a result, pulsed dose delivery of oxygen was also developed to conserve the amount of oxygen that was administered by delivering the oxygen at the beginning of inspiration to eliminate the waste of the oxygen in the anatomical dead space [6].

In mechanical ventilation, the standard delivery method of oxygen is to provide gas at 50 psig from a wall source. Oxygen is mixed with air to deliver the prescribed F_iO_2. In the absence of a high-pressure source, continuous low-flow oxygen from a portable source, i.e., liquid container or oxygen cylinder, is provided and then mixed with atmospheric air to deliver a variable oxygen concentration to the patient (the F_iO_2). In this instance, the delivered F_iO_2 is based on the minute ventilation, inspiratory to expiratory time ratio, and oxygen flow. Low-flow oxygen is typically delivered into a reservoir bag connected to the inlet of the ventilator's air compressor. Rodriguez et al., using a test lung model, studied the possibility of using a POC with and without pulsed dose delivery of oxygen to supply the oxygen required for a mechanical ventilator [7]. Based on these results, enough oxygen was present in a test lung for theoretical oxygen exchange to take place at the alveolar level. The maximal oxygen concentration from the POC (approximately 93%) at the alveolar level was at the beginning of each breath, with the remainder of the delivered breath composed of atmospheric air.

Due to the potential that exists for conserving oxygen with a POC and pulsed dose delivery with mechanical ventilation, we hypothesize that it is possible to oxygenate patients with ALI using pulsed dose oxygen delivery from a portable oxygen concentrator.

3.0 METHODS

The experimental protocol described was performed in accordance with the National Institutes of Health guidelines for the use of experimental animals in research. The Institutional Animal Care and Use Committee at the University of Cincinnati approved the experimental protocol. Funding for this project was provided by a grant from the USAF.

3.1 Animal Preparation

Fifteen locally bred pigs (mean ± standard deviation (SD) weight, 39.9±3.3 kg) were pretreated with intramuscular telazol (5 mg/kg), xylazine (1 mg/kg), and atropine (0.54 mg/kg). They were then intubated with 7.5 French endotracheal tubes. A surgical plane of anesthesia was maintained with isoflurane. Auricular veins were cannulated for intravenous access. A femoral artery catheter was placed via cut-down for blood pressure measurement and arterial blood gas sampling. A right internal jugular catheter was placed via cut-down and a right heart catheter was advanced into the pulmonary artery to allow measurement of cardiac output, mixed venous blood sampling, and administration of oleic acid via the proximal port. At this point, inhaled anesthesia was discontinued and a continuous infusion of propofol (15-25 mg/kg) was then used for sedation. To prevent intravascular collapse during administration of oleic acid, warm Lactated Ringer's solution (5-10 mL/kg/h) was infused continuously, with boluses as needed. If circulatory collapse or arrhythmia were encountered after administration of oleic acid, chest compressions, electrical defibrillation, and epinephrine (0.1-1 mg/kg) boluses were used as needed.

3.2 Lung Injury Protocol

After baseline hemodynamic measurements and arterial blood gases (ABGs), 0.06-0.09 mL/kg oleic acid (O1008-25G; Sigma-Aldrich, St. Louis, MO) was administered through the proximal port in the pulmonary artery (PA) catheter to induce acute lung injury [8-11]. This was done with a target goal of a P:F ratio of <300. The oleic acid was diluted in normal saline to a total volume of 15 mL. To ensure dissolution, the solution was mixed using a Vortex-Genie 2 (Scientific Industries, Inc., Bohemia, NY). The solution was given every 2 minutes in 2-mL aliquots. ABGs were drawn and analyzed with an i-Stat machine (Abaxis, Union City, CA). When the P:F ratio was less than 300, the experimental portion began. After finishing the first mode of oxygen delivery, each pig required redosing of oleic acid to ensure a P:F less than 300 for the second mode of oxygen delivery.

3.3 Ventilator and Oxygen Delivery

At the conclusion of the surgical procedures, the pigs were ventilated using the Impact 731 ventilator (Impact Instrumentation Inc., West Caldwell, NJ). This ventilator was chosen because it is used by the CCATTs. In a previous study performed at our institution [7], a POC was used to provide oxygen using two methods: (1) continuous flow into a reservoir bag and (2) oxygen pulsed into the patient end of the ventilator circuit. In this study, as well as ours, the oxygen from the POC came into the circuit, directly at the endotracheal tube. We used the SeQual Eclipse II, which was selected for its oxygen generating capabilities, as it is capable of generating 3 Lpm of continuous flow oxygen, the highest of any commercially available POC. For purposes of comparison, the devices were operated at the maximum output, 3 Lpm of continuous flow and a pulse dose of 180 mL. This POC was modified by the manufacturer to trigger on positive pressure. Continuous flow of oxygen was aided by a reservoir bag (Figure 1). Data from the ventilator regarding each breath was collected by placing a fixed orifice pneumotachograph (NICO 2, Respironics Phillips, Andover, MA) in the circuit to monitor tidal

volume, airway pressures, and flow. Eight pigs were treated with volume control ventilation, while seven were treated with pressure control.

Figure 1. Impact Ventilator Connected to SeQual 2 POC *(note reservoir bag attached to ventilator circuit)*

3.4 Experimental Protocol

For volume control, baseline ventilator settings were used to minimize variance between all animals: PEEP of 0 mmHg, respiratory rate (RR) of 14 breaths per minute, tidal volume (V_T) of 450 mL, and F_iO_2 of 0.4. For pressure control, baseline settings were the same and pressure was maintained to provide a V_T of 450 mL. Our goal was to maintain an adequate oxygen saturation (S_pO_2) (94%) at a nontoxic F_iO_2. As stated before, the POC was set to deliver either a continuous flow of 3 Lpm or a pulsed dose of 180 mL (approximately 40% of the V_T). Room air was used to supplement the remainder of the V_T as is done with conventional mechanical ventilation. The addition of the pulse dose of oxygen augmented volume during volume control. This required manual reduction of the set V_T to maintain a delivered V_T of 450 mL. During pressure control ventilation, the addition of the pulse volume did not alter V_T, as flow of the ventilator is controlled to maintain peak pressure. We placed a catheter connected to an infrared, fast-response O_2 analyzer (Oxigraf, Mountain View, CA) at the distal end of the endotracheal tube to continuously measure the oxygen content of the gas in the circuit.

We designed the study as a crossover trial, so each animal served as its own control. Once ALI was achieved, we randomized each animal to start in continuous flow of oxygen or a pulsed dose delivery of oxygen. ABGs, cardiac output, and ventilator data were recorded every 15 minutes [12] for a total of 45 minutes per mode. At the conclusion of the first mode of oxygen delivery, we again ensured that each animal was starting the next mode with a P:F ratio <300. In each animal, this required redosing the oleic acid. The oxygen delivery was then changed to the other method for 45 minutes, with data collected every 15 minutes.

3.5 Statistical Analysis

P:F ratios were calculated by dividing the P_aO_2 by the F_iO_2. All data are expressed as mean ± SD. Student's *t*-test was used to compare the data. A $p<0.05$ was considered significant.

4.0 RESULTS

4.1 Ventilator Data and Hemodynamic Monitoring

There were no significant differences in RR, V_T, end-tidal carbon dioxide ($ETCO_2$), mean airway pressure, or peak airway pressure. Respiratory rate was adjusted to maintain normal physiologic values of dissolved carbon dioxide. However, this was not statistically or clinically significant (Tables 1 and 2). For purposes of oxygenation, the F_iO_2 will be discussed with the P:F ratios and the P_aO_2. Peak inspiratory airway pressures in each mode of ventilation were not significantly different. When visualizing the waveforms produced from each breath, there is a noticeable difference in the flow rates between the pulsed dose delivery and continuous flow in volume control, with representative curves shown in Figures 2 and 3. The pulsed dose technique resulted in an increase in inspiratory flow for the first 200 ms.

Table 1. Ventilator Data[a]

Measurement	Volume Control		Pressure Control	
	Mean	SD	Mean	SD
Pulsed Dose				
RR	14.1	2.5	14.3	1.5
$ETCO_2$	48.0	6.7	49.9	6.2
V_T (mL)	458.2	21.5	451.4	12.8
Peak Inspiratory Pressure (cm H_2O)	24.3	3.9	23.4	5.3
Mean Airway Pressure (cm H_2O)	4.4	1.0	6.7	2.9
Continuous Flow				
RR	13.5	2.8	13.4	0.9
$ETCO_2$	47.4	6.2	53.2	5.4
V_T (mL)	451.4	12.7	444.5	15.6
Peak Inspiratory Pressure (cm H_2O)	26.1	3.4	24.0	5.2
Mean Airway Pressure (cm H_2O)[b]	4.1	0.9	6.5	2.7

[a]All $p>0.05$ except as noted.
[b]$p=0.03$.

Table 2. Physiologic Data[a]

Measurement	Volume Control		Pressure Control	
	Mean	SD	Mean	SD
Pulsed Dose				
Heart Rate	102.7	21.5	92.0	7.6
Systolic Pressure (mmHg)	142.03	19.5	145.4	21.4
Diastolic Pressure (mmHg)	92.2	15.1	93.3	20.8
Mean Arterial Pressure (mmHg)	110.29	16.7	109.7	25.0
PA Systolic Pressure (mmHg)	38.0	6.2	38.0	3.4
PA Diastolic Pressure (mmHg)	24.0	8.8	23.8	4.6
Continuous Flow				
Heart Rate	100.1	18.4	92.9	18.4
Systolic Pressure (mmHg)	144.5	21.3	140.8	21.3
Diastolic Pressure (mmHg)	96.1	14.93	87.0	14.9
Mean Arterial Pressure (mmHg)	113.7	17.21	106.6	17.2
PA Systolic Pressure (mmHg)	39.3	5.0	36.6	5.0
PA Diastolic Pressure (mmHg)	24.5	9.0	22.6	9.0

[a]All $p>0.05$.

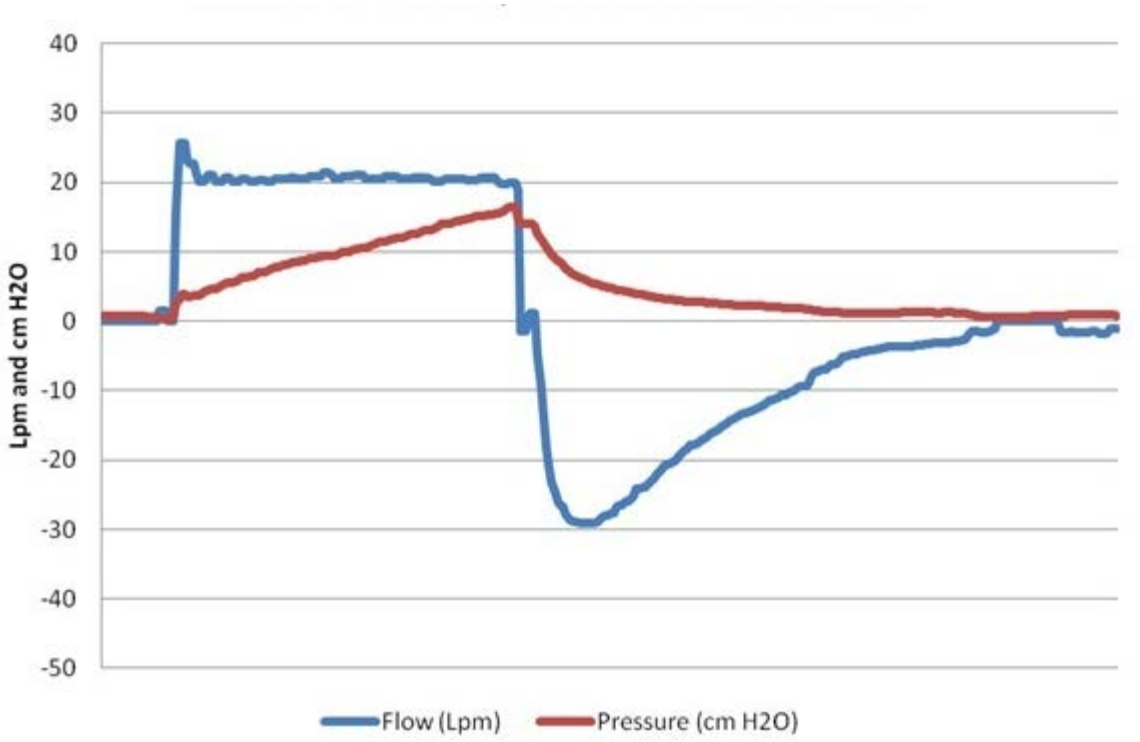

Figure 2. Volume Control, Continuous Flow Oxygen

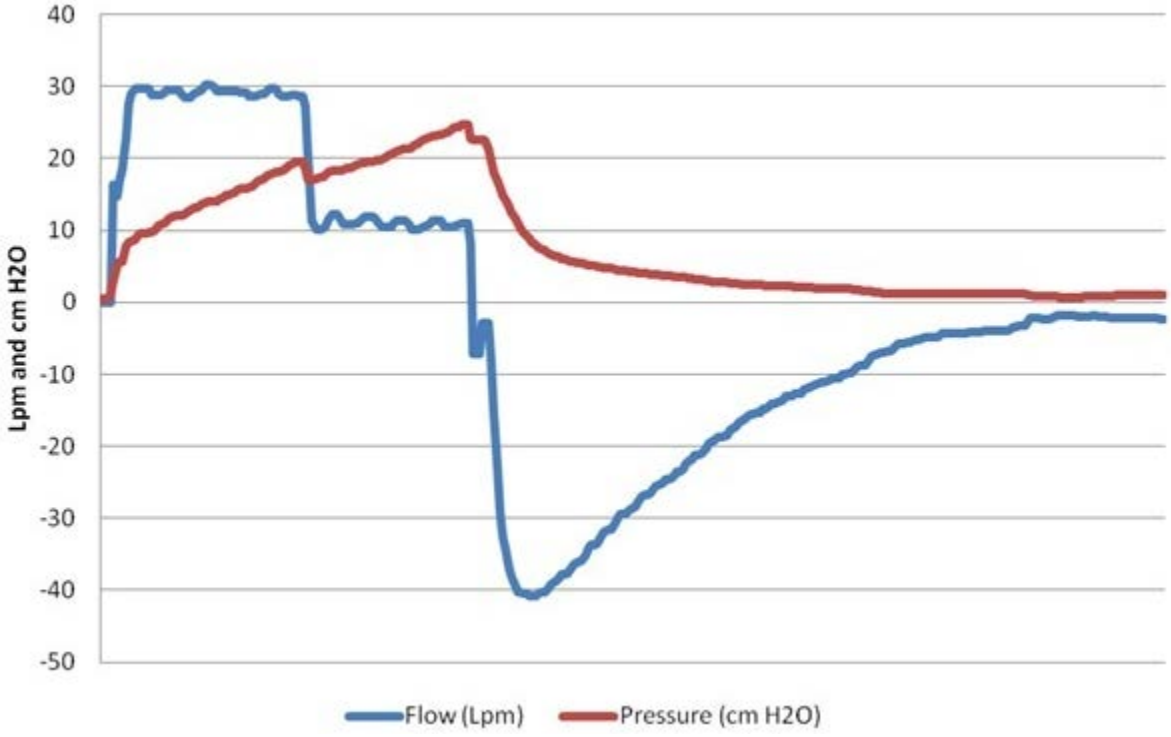

Figure 3. Volume Control, Pulsed Dose Oxygen

Hemodynamic monitoring was accomplished with continuous blood pressure monitoring, cardiac output monitoring, and pulmonary pressure monitoring. After administration, the pulmonary arterial pressures were elevated over baseline. However, in comparison of hemodynamic variables, between the two different modes of oxygen delivery, no single value was found to be statistically significant (Table 3).

Table 3. Oxygenation, Pulsed Dose vs. Continuous Flow

Measurement	Volume Control		Pressure Control		*p* Value
	Mean	SD	Mean	SD	
Pulsed Dose					
S_pO_2 (%)	95.7	3.0	94.5	4.1	0.08
F_iO_2	0.51	0.08	0.47	0.08	0.47
P_aO_2 (mmHg)	202.0	77.7	159.0	59.2	0.05
Final P:F	383.8	119.8	291.5	123.2	0.02
Starting P:F	215.0	56.3	200.0	72.6	0.66
P:F Difference	168.8	96.1	89.0	74.5	0.04
Continuous Flow					
S_pO_2 (%)	94.9	2.6	95.5	2.1	0.12
F_iO_2	0.49	0.08	0.48	0.02	0.27
P_aO_2 (mmHg)	158.4	59.1	146.9	59.1	0.74
Final P:F	322.5	82.9	303.7	82.9	0.56
Starting P:F	230.9	42.9	224.6	44.9	0.62
P:F Difference	91.7	65.4	79.1	61.4	0.28

4.2 Oxygenation-Volume Control

The baseline P:F ratios for the pulsed dose and continuous flow techniques, 215.0±56.3 and 230.9±42.9, respectively, were not statistically different, p=0.50 (Table 4). The S_pO_2 values in the two different oxygen delivery methods were also not statistically different: 95.7% vs. 94.9%, p=0.13. The P_aO_2 was found to be significantly greater in the pulsed dose technique versus continuous flow, 202.0±77.7 vs. 158.38±59.1, p=0.03. Both methods showed an increase in the P:F ratio over baseline. However, the increase from baseline of the P:F, 168.8±96.1 for the pulsed dose and 91.7±65.35 for the continuous flow, was found to be statistically different, p= 0.002. The peak F_iO_2 was not found to be statistically different between the two techniques of oxygen delivery at 0.51 and 0.49, p=0.24.

4.3 Oxygenation-Pressure Control

The baseline P:F ratios for the pulsed dose and continuous techniques, 200.0±72.6 and 224.6±42.9, respectively, were not statistically different, p=0.53 (Table 3). The S_pO_2 values with the two different techniques were also not statistically different, 94.5% vs. 95.5%, p=0.13. The P_aO_2 was not statistically significant between the pulsed dose technique and the continuous flow technique, 159.0±59.2 vs. 146.9±59.1, p=0.46. The F_iO_2 was not found to be statistically different between the two techniques of oxygen delivery at 0.47 and 0.48. Both techniques showed an increase in the P:F ratio over baseline. However, the difference for the two techniques, 89.0±74.5 for the pulsed dose and 79.1±65.4 for the continuous flow, was not statistically different, p= 0.67 (Table 4).

Table 4. Oxygenation, Volume vs. Pressure Control

Measurement	Pulsed Dose		Continuous		*p* Value
	Mean	SD	Mean	SD	
Volume Control					
S_pO_2 (%)	95.7	3.0	94.9	2.6	0.09
F_iO_2	0.51	0.08	0.49	0.08	0.67
P_aO_2 (mmHg)	202.0	77.7	158.4	59.1	0.03
Final P:F	383.8	119.8	322.5	82.9	0.03
Starting P:F	215.0	56.3	230.9	42.9	0.54
P:F Difference	168.8	96.1	91.7	65.4	0.002
Pressure Control					
S_pO_2 (%)	94.5	4.1	95.5	2.1	0.10
F_iO_2	0.47	0.08	0.48	0.02	0.85
P_aO_2 (mmHg)	159.0	59.2	146.9	59.1	0.74
Final P:F	291.5	123.2	303.7	82.9	0.57
Starting P:F	200.0	72.6	224.6	44.9	0.67
P:F Difference	89.0	74.5	79.1	61.4	0.73

4.4 Volume Control vs. Pressure Control

Continuous flow of oxygen in the two different ventilator modes was not found to be significantly different in any respect. However, the increases between the two different ventilator modes for the P_aO_2, P:F difference, P:F, and F_iO_2 were all found to be significantly different (Table 3) using pulsed dose oxygen delivery, with volume control having the greatest increase.

5.0 DISCUSSION

Our study shows that it is possible to use a portable oxygen concentrator, specifically, pulsed dose oxygen delivery, to provide adequate oxygenation during mechanical ventilation for patients with acute lung injury using equipment deployed by the USAF CCATTs. Both methods of oxygen delivery, pulsed dose and continuous flow, showed an improvement in the P:F ratio over baseline, with both volume control and pressure control ventilation. While our study was not designed to prove that a pulsed dose delivery system would be a better method of oxygen delivery, it is interesting to note that pulsed dose delivery did result in a significant increase in the P:F ratio in volume control.

This difference between the two methods of oxygen delivery is likely due to the pulsed dose delivery method resulting in a higher dose of breathable oxygen delivered to the subject's airspaces. Because all of the oxygen is delivered at the initiation of the breath, a greater percentage of oxygen can be delivered to the alveolar spaces where the gas exchange occurs. This results in the last portion of the breath ventilating the anatomic dead space. This improves the efficiency of oxygen use. We did note that use of the pulse dose technique resulted in an increase in flow for the first 200 ms. This results in a stair-step flow pattern and the requirement to reduce the set V_T manually, but the V_T and total volume of oxygen remained unchanged without a significant increase in airway pressures, when compared with continuous flow of oxygen. When comparing the flow and pressure curves (Figures 2-5), there is a noticeable notch in all of the curves with pulsed dose oxygen delivery, which signifies the end of the pulsed dose.

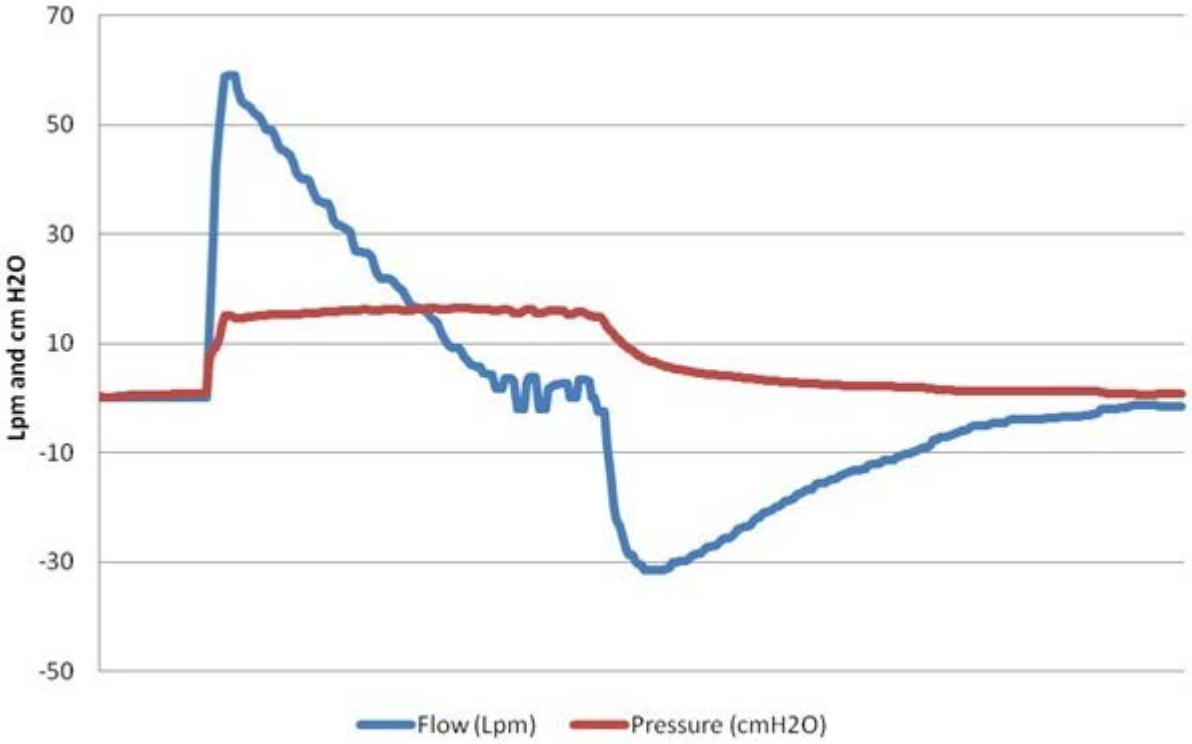

Figure 4. Pressure Control, Continuous Flow Oxygen

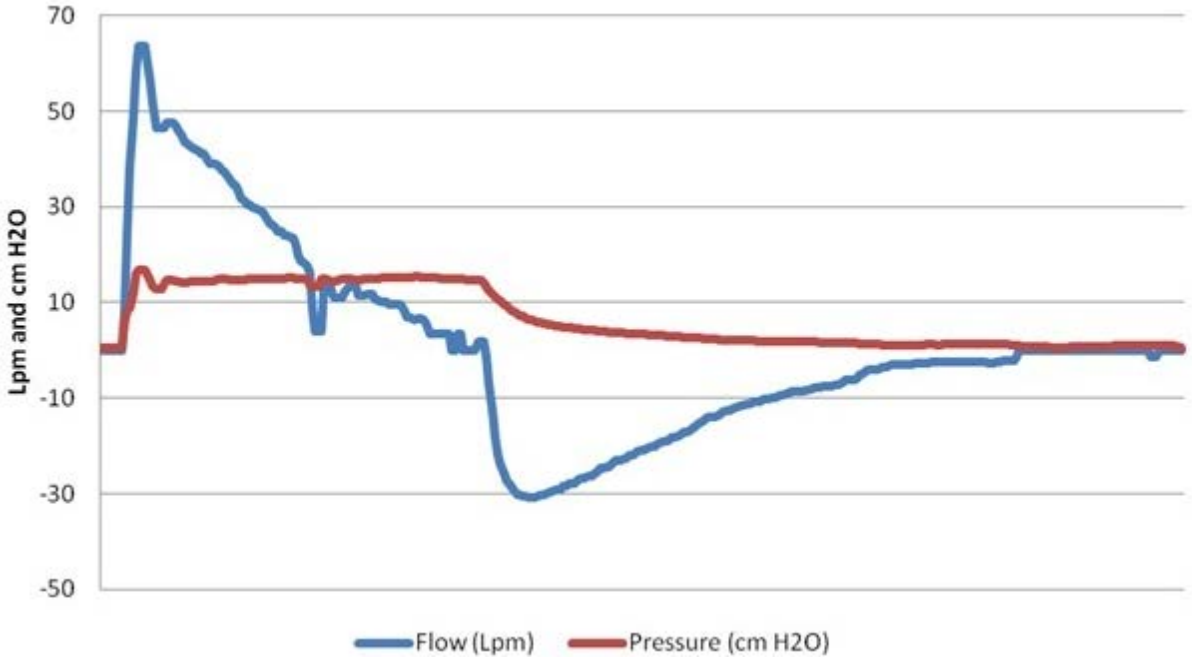

Figure 5. Pressure Control, Pulsed Dose Oxygen

Based on our results, using a POC with pulsed dose oxygen delivery for oxygenation would be beneficial for transportation of critically ill patients. In our experiment, we were able to provide enough oxygen without being tied to oxygen cylinders or a wall source. This could be extremely beneficial to transporting critically ill patients in the military, where transit times from forward-deployed locations average 8 hours for each leg of transit. Using a standard size E oxygen canister, three cylinders would be required to provide the same amount of oxygen for an 8-hour journey as the equivalent oxygen that was used in our experiments. These three cylinders would provide significant constraints on storage during flight and manpower associated with managing these cylinders. In addition, this would be required for each patient. As stated above, current Air Force doctrine prohibits the use of cylinders on aircraft. Liquid oxygen systems are used for oxygen delivery in critically ill patients, which have significant requirements for both storage and manpower. By using POC, especially the pulsed dose delivery of oxygen, many of the current difficulties would be eliminated, while still maintaining adequate oxygen delivery. In essence, as long as there is electricity, oxygen is available. This option also exists in situations where there is no available electricity, as all commercially available POCs have extensive battery life.

The limited oxygen flow from a POC would not provide enough oxygen for all transported patients. The maximum F_iO_2 is approximately 0.60, and with faster respiratory rates and higher minute volumes, this value falls. However, we believe that a ventilator concentrator system running from a generator or batteries would allow the delivery of oxygen in austere environments for prolonged times while not requiring the logistic burden of liquid or compressed gas cylinders. Additionally, work by our group suggests that a majority of injured trauma patients can have oxygenation supported at oxygen flows of < 3 Lpm [13,14]. A complete solution would require a hybrid system using the POC for the majority of oxygen needs while relying on a smaller compressed gas supply to reach F_iO_2 near 1.0.

6.0 LIMITATIONS

There are a number of limitations to our study and the current method. First, we used a manufacturer-modified POC that triggered on positive pressure to deliver the oxygen. This is different from the standard trigger mechanism, which triggers on negative pressure (inspiration). This required the PEEP to be set to 0 cmH_2O for the oxygen to be introduced into the breath. At elevated baseline pressures, this purely pneumatic system auto-triggers or misses triggers, preventing optimum oxygen delivery. We are currently designing a system that would allow the ventilator to trigger the POC using an electronic signal and automatically compensate for changes in the delivered V_T due to the volume of the pulsed dose bolus.

Second, the current method relies on manual correction of V_T, which has safety concerns. For instance, if the POC is disconnected, the tidal volume may be reduced precipitously. Appropriate alarm settings in a clinical scenario would be essential.

Third, all the animals were sedated to a point where spontaneous breathing was absent. In a situation of increasing minute ventilation, the F_iO_2 from the concentrator may fall. For comparison purposes, we only tested the methods at the maximum settings. Testing across the range of pulse dose values and tidal volumes would be important prior to clinical testing.

7.0 CONCLUSIONS

We have been able to show that a portable oxygen concentrator is capable of providing adequate oxygen for arterial oxygenation using both continuous flow and pulsed dose delivery. This provides an alternative to standard oxygenation techniques, especially in the transport of critically ill patients and in austere environments, where delivering oxygen supplies is challenging. It may also be helpful in the transportation of patients who require oxygen therapy while requiring mechanical ventilation and supplemental oxygenation. However, human studies should be performed to further prove the efficacy.

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LIST OF ABBREVIATIONS AND ACRONYMS

ABG	arterial blood gas
ALI	acute lung injury
CCATT	Critical Care Air Transport Team
$ETCO_2$	end-tidal carbon dioxide
F_iO_2	fraction of inspired oxygen
P:F	P_aO_2: F_iO_2
PaO_2	arterial oxygen concentration
PEEP	positive end-expiratory pressure
POC	portable oxygen concentrator
RR	respiratory rate
SD	standard deviation
S_pO_2	oxygen saturation
USAF	United States Air Force
V_T	tidal volume